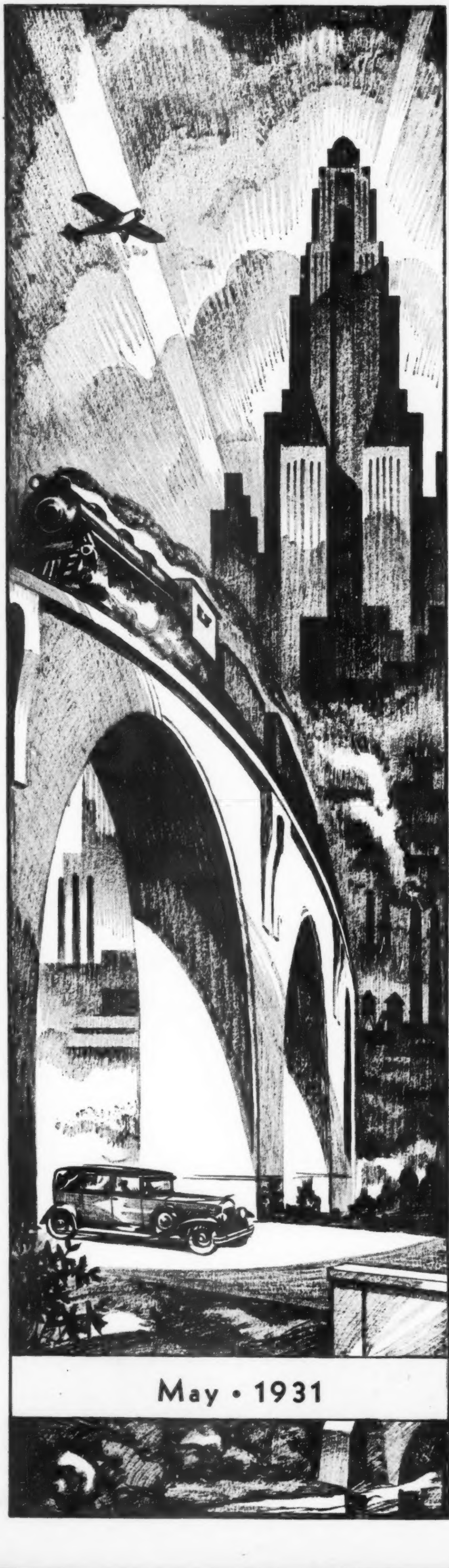

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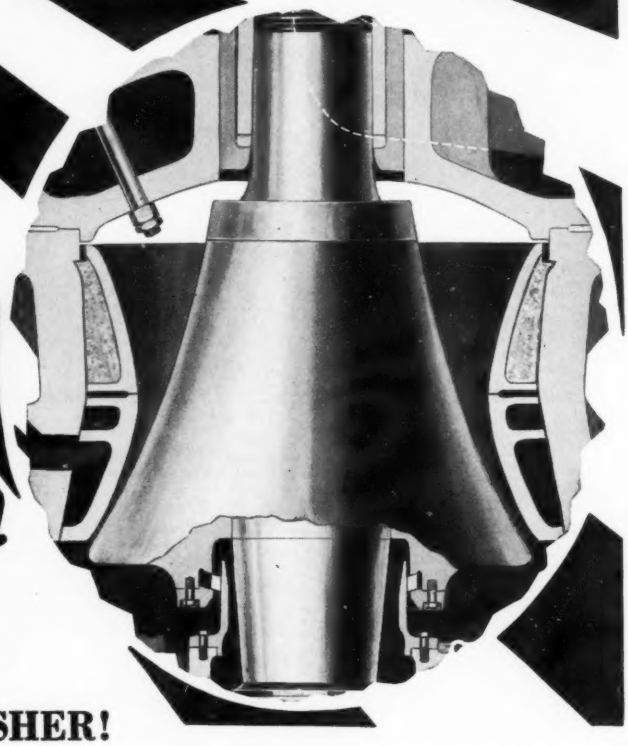

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The Proportioning of Concrete For Strength, Durability and Impermeability[1]

By A. T. GOLDBECK

Director, Bureau of Engineering, National Crushed Stone Association

One of the most important problems confronting the ready-mixed concrete producer is to provide acceptable concrete which is suitable for many different purposes and to effectively accomplish this a working knowledge of the methods of proportioning concrete is essential. The producer of ready-mixed concrete is frequently required to produce concrete having certain desired properties such as a given crushing strength or transverse strength without being limited as to the proportions, thus giving him the opportunity of exercising his ingenuity to produce the most economical concrete of the desired characteristics. The following discussion on proportioning should prove particularly helpful.

Introduction

IN approaching the paper which has been assigned to me I have tried to place myself in the position of the average ready mixed concrete producer and I have asked myself what information I should like to have on the proportioning of concrete if I were in the ready mixed concrete business. There are a great many theories on the proportioning of concrete, some of them of a more or less complex nature and all of them more or less interrelated to one another. It is not at all my purpose to discuss these theories, but rather do I wish to give you a practical working basis upon which the proportions of concrete mixtures, suitable for the purpose in hand, may readily be obtained. It is useless to make a complicated matter out of a really simple procedure, and I know that you are interested in obtaining the most suitable proportions of concrete in the simplest possible manner.

The Composition of Concrete

Before discussing the proportioning of concrete or the effect of proportions on the strength, durability and impermeability, let us get clearly in mind some of the basic facts regarding the composition of concrete. Concrete consists essentially of a mixture of cement paste and aggregate. The cement paste is the binding medium which glues the aggregate together into a solid mass. The properties of the final mixture are affected by a number of different factors, the principal one of which is the amount of water used in mixing the ingredients together. The cementing properties of the cement paste are greatly affected by the amount of mixing water used. It is now well established that the greater the quantity of water employed, the weaker is the resulting cement paste and consequently the weaker is the concrete produced.

The ready mixed concrete producer may be called upon to make concrete complying with two different types of specifications, one of which calls for certain fixed arbitrary proportions such as 1:2:4 and the other requiring the production of concrete having certain desired properties such as a given crushing strength at the end of 28 days or a given transverse strength and also a given workability. In the present paper we are concerned primarily with concrete produced under the second type of specification in which the producer may exercise his ingenuity to produce the most economical concrete satisfying the requirements.

[1] Presented before the First Annual Convention of the National Ready Mixed Concrete Association, Hotel Jefferson, St. Louis, Mo., January 26, 1931.

The fundamental conception of concrete, however, remains the same no matter what type of specification is in force. Concrete must be supplied for all types of construction which require concretes having different degrees of workability and different strengths and other characteristics. One of the first items, therefore, which confronts the ready mixed concrete producer in proportioning concrete for a given purpose is the fact that he must turn out concrete which is suitable for the purpose from the standpoint of consistency or workability and he must so contrive the relative proportions of water, cement, fine and coarse aggregates that the required strength will be secured with the utmost economy. Were it not for this factor of workability and the necessity of producing a plastic mass, it might be possible to use only enough water in the mixture to hydrate the cement and no more. But as a matter of fact, with our present methods of mixing and placing concrete, it is always necessary to use more mixing water than just enough to hydrate the cement, otherwise the mixtures would be far too dry for proper workability.

One might conceive of the final mixture of concrete, therefore, as a mixture of coarse and fine aggregates with cement which has combined with a certain proportion of the mixing water and, in addition, there is a certain amount of water which does not combine with the cement but which remains in the mass as free water. This free, or uncombined water, occupies space in the mass and if it later evaporates it leaves void spaces. The greater amount of free water present, the greater will be the voids and the more porous will be the concrete. In general, the higher the water-cement ratio, that is, the ratio of the volume of water to the volume of cement in the mixture, the greater will be the amount of free water present in the concrete, and consequently the more porous will that concrete be. It must be self-evident that high porosity in concrete must make for high absorption and generally a high degree of permeability and because of the high absorption the action of frost on porous concrete is apt to be unusually severe. Such concretes are therefore likely to be non-durable. It is quite evident that the water-cement ratio, no matter how it may be expressed, whether in terms of cubic feet of water per sack of cement or in gallons of water per sack of cement is a primary consideration in the proportioning of concrete.

Mr. F. R. McMillan of the Portland Cement Association, in his excellent book entitled, "The Basic Principles of Concrete Making" gives a very fine illustration of the proportions of aggregate, cement, combined water and uncombined water in concretes of various proportions. His Fig. No. 1 is reproduced herewith. It will be noted that the uncombined water in mixtures, having a slump of 3 to 4 inches may be from 80 to 90 per cent of the total water added to the mixture. This diagram also brings out very forcibly the well-known fact that for a given consistency, lean mixtures require a higher water-ratio than rich mixtures of concrete.

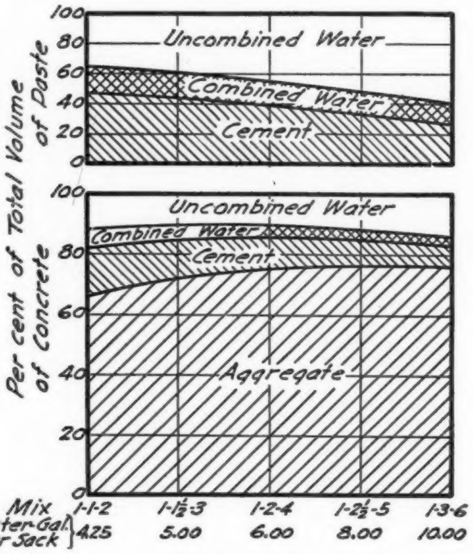

FIG. 1. ANALYSIS OF CONCRETE MIXTURES OF UNIFORM CONSISTENCY
Slump 3 to 4 in.

Effect of Water-Cement Ratio on the Strength of Concrete

It seems almost trite to even mention the relation of compressive strength of concrete and the water-cement ratio used in the concrete mixture. This subject has been so fully covered by concrete literature of recent years, particularly that eminating from the laboratory of the Portland Cement Association where this relation was originally established under the guidance of D. A. Abrams. Prof. Abrams showed that as long as the mixtures were plastic and further, as long as other conditions, including materials, character of curing and temperature of curing were identical, the compressive strengths to be expected were entirely governed by the ratio of volume of water to the volume of cement used in the mixture. It needs emphasis here, however, that the well-known water-cement-ratio compressive-strength curve established by Prof. Abrams is an average curve from which there may be deviations brought about by deviations from the conditions which obtained at the time the Portland Cement Association tests were made.

For illustration, all of the following factors may influence the strength of concrete at a given age in addition to the influence of the water-cement ratio.

a. The character of the cement.
b. The character of the aggregates used.
c. The temperature at which curing takes place.
d. The character of the curing.

It is not safe to follow blindly the water-cement ratio law shown in Fig. 2 and established originally by

the Portland Cement Association, without taking into consideration at least the four factors above mentioned and it is very important that ready mixed concrete

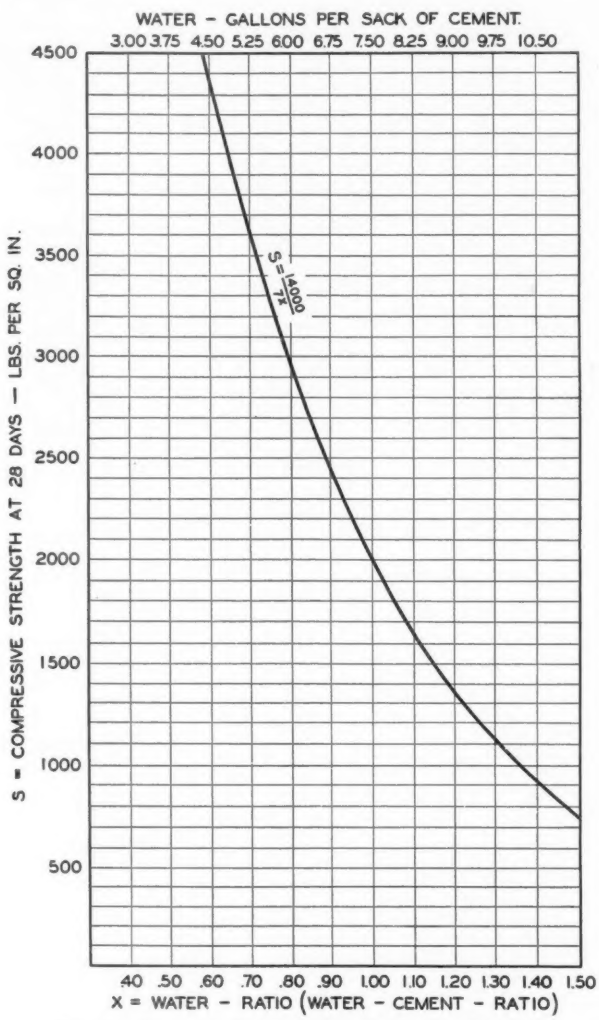

Fig. 2. Typical Water-ratio Strength Relation

producers understand this in order that they may produce concrete most economically and fully satisfying the requirements of the specifications. The fact that there are deviations from the general water-cement ratio law does not at all discredit or render useless the principles which Prof. Abrams has established, but, on the other hand, the recognition of these deviations renders the principles all the more useful. It will be worth while to consider in a little detail just what effect these deviations have and to point out how they may be taken into account in the proper design of concrete.

Effect of Characteristics of Cement

The strength of almost all Portland cements has been increased in recent years and at the present time we have a number of cements purposely designed to attain their strength at early periods. Even among the standard brands of portland cement there is a variation in the rate of gain in strength. This is well

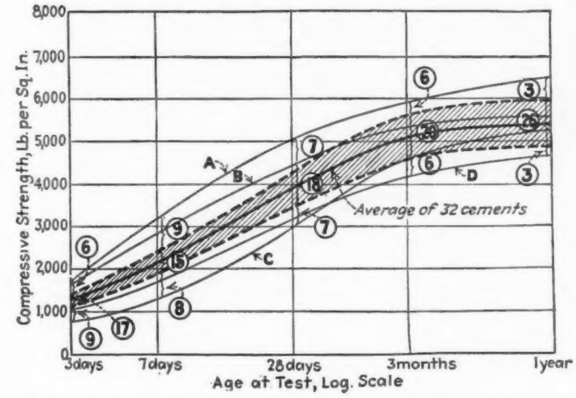

Fig. 3. Age-Strength Relations for 32 Cements
Mix 1-2.4-3.6 by weight. Water-cement ratio 6.2 gal. per sack. Specimens cured in moist room. Diagram from "The Basic Principles of Concrete Making" by F. R. McMillan

brought out in the accompanying Fig. 3 showing the age-strength relation for 32 cements which were studied by Committee C-1 on Portland Cement of the American Society for Testing Materials. It will be noted that at the age of 7 days the compressive strength of one cement was more than double that of another and at 28 days one cement had a compressive strength of 5,000 lbs. as against only 3,000 lbs. for the cement of lowest type. There is a tendency, however, for all of the cements to approach more closely the same strength at the age of one year and later.

Obviously, if these different cements were used in concrete made with different water-cement ratios, the relation between the compressive strength and the water-cement ratio would not be expressed by a single curve such as in Fig. 2 but there would be a separate curve for each of the cements used. It is important, therefore, that the ready-mixed concrete producer establish or have established for him the water-cement ratio compressive-strength relation for the particular cement with which he is working.

Effect of Aggregates

Aggregates vary in their characteristics, not only coarse aggregates, but fine aggregates as well. These variations include not only gradation but variations in moisture content, in degree of cleanliness, including the presence of surface coatings, variation in absorption, in degree of angularity and roughness of surface and in the possible presence of deleterious materials such as unsound particles, organic materials, clay lumps and coal. All of these deleterious materials and characteristics have their effect on the strength of the resulting concrete.

Thus, for illustration, the presence of water in the aggregates influences the water-cement ratio which is effective in controlling the strength, as does also the

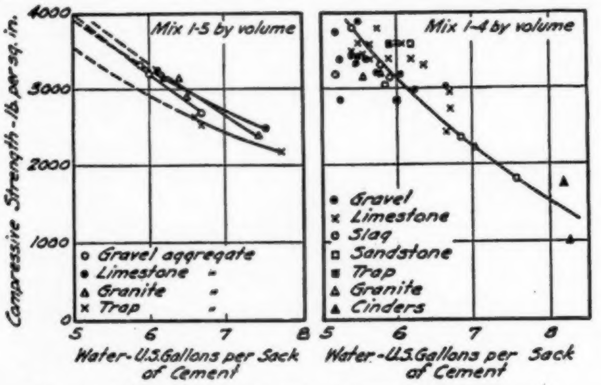

FIG. 4. WATER-CEMENT-RATIO CURVES FOR DIFFERENT AGGREGATES

Grading variable; moist cured; age at test 28 days. Diagram from "The Basic Principles of Concrete Making" by F. R. McMillan

amount of absorption of the aggregates. The former has a detrimental effect, the latter generally is beneficial. Highly polished aggregates may have a detrimental effect in lowering the strength, particularly the beam or transverse strength of concrete because of the decreased bond between the mortar and the coarse aggregate. Rough aggregate may furnish a better bond. Coatings which are difficult to remove naturally decrease the strength of the concrete because of the decreased bond.

The gradation of the aggregate has its influence, particularly in affecting the workability of the concrete and this is particularly true when fixed proportions are used rather than in the case of the designed mix. The gradation of aggregates does not seem to be a highly important factor when latitude is allowed in the proper combination of fine with coarse for the attainment of the desired degree of workability. Gradation may have an important effect on economy.

In Fig. 4 is shown a set of water-cement ratio curves

TABLE I—PROPERTIES OF CONCRETE[1]

No.	Total Water	Wt. per Cu. Ft.	Flow	Workability	W/C[2]	Bags of Cement per Cu. Yd.	Combined Fineness Modulus	Crushing Strength	Modulus of Rupture
1	13.1	154.5	159	3	0.63	6.13	5.57	4090	701
2	14.3	154.1	161	2 - 3	0.69	6.05	5.45	4010	691
3	13.7	154.3	163	2+	0.66	6.03	5.58	4000	733
4	14.1	153.7	162	2	0.68	6.11	5.36	4060	758
5	14.1	153.6	163	2	0.68	6.07	5.43	4110	724
6	13.8	154.2	166	2	0.66	6.09	5.50	4170	767
7	13.9	153.7	168	2	0.67	6.01	5.55	4300	745
8	13.8	153.9	172	2+	0.66	6.00	5.69	3910	763
9	13.8	154.9	169	2+	0.66	6.12	5.60	4180	774
10	13.6	154.7	163	2+	0.65	6.09	5.66	4010	785
11	13.4	154.5	174	2 - 3	0.64	6.06	5.79	3970	724
12	13.2	154.5	167	3	0.63	6.13	5.78	4010	725

[1] Coarse Aggregate: Limestone No. 35, Sp. Gr. 2.75, 3.3% wear, Sand, Massaponax No. 48.

[2] W/C—Water-cement ratio, i. e., ratio of volume of water to volume of cement.

applying to the respective aggregates used in the particular tests from which these curves were plotted. Each aggregate has its own water-cement ratio curve and this is the important fact to remember. The aggregates, however, do not play as important a part in the compressive strength of concrete as is the case with transverse strength, but, in any event, whether the concrete is designed for compression or for beam strength full account should be taken of the kind of aggregate employed. This is accomplished in the method of design later proposed.

Effect of Gradation of Aggregate

In Fig. 5 are shown the results of studies made to determine the effect of gradation of coarse aggregate on the strength of the resulting concrete. The results are plotted on a triaxial diagram for convenience in showing the variations in gradation. It is to be noted that considerable variation in the percentage of the various sizes used does not seem to show any great variation in either the compressive or transverse strength of the resulting concrete. All of the concretes had approximately the same cement content, 6 bags per cu. yd., and all were mixed to about the same consistency, using proportions of 1:2:3½ by dry, loose volume.

In Table I are shown the essential data in connection with this test. The numbers under the column headed "Workability" have the following meanings:

1 = excellent
2 = good
3 = medium
4 = poor
5 = very poor

They represent the judgment of the operator.

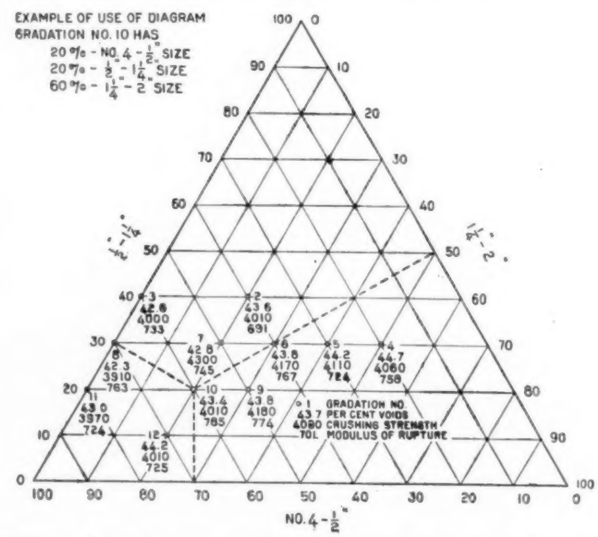

FIG. 5. EFFECT OF GRADATION OF CRUSHED STONE ON PERCENTAGE OF VOIDS AND STRENGTHS OF CONCRETE (SQUARE OPENING SIEVES)

Effect of Surface Coatings

Obviously, those surface coatings which are not displaced in the concrete mixer must affect the bond of

the mortar with the coarse aggregate and therefore seriously affect the strength of the concrete. Some clay coatings are of this nature and perhaps also some types of dust coatings have the same effect. Not all dust coated stone, on the other hand, affects the strength of concrete as proven by tests made by the writer and published in the 1929 and 1930 Proceedings of the American Society for Testing Materials under the report of Committee C-9.

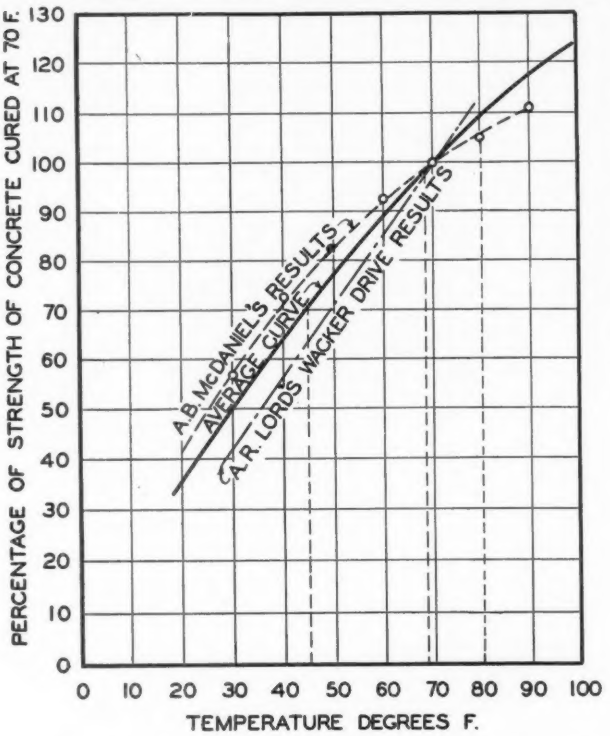

FIG. 6. EFFECT OF CURING TEMPERATURES ON COMPRESSIVE STRENGTH OF CONCRETE AT 28 DAYS

Perhaps enough has been said, however, to show that the aggregates do play their part in affecting the final strength of the concrete and, accordingly, when determining the proper proportions to use, it is essential that this determination be made with the particular aggregates being employed in the mixture.

Effect of Curing Temperature

The hydration of cement is a chemical activity and like other chemical activities it is accelerated by higher temperatures. The tests on the effect of curing temperatures on the compressive strength of concrete are rather meager. It is commonly known, however, that the strength of concrete is reduced by low temperatures and is increased by high temperatures. This point was brought out by A. R. Lord and recognized by him in his control of the concrete used on the Wacker Drive in Chicago. Tests made many years ago by Prof. A. B. McDaniel at the University of Illinois Engineering Experiment Station also show the effect of temperature on the strength of concrete.[1] The results of these experiments and those obtained by Mr. Lord are shown in Fig. 6. It is obvious from this curve that if the concrete is designed to have a given strength at 70° F., it would have only 70 per cent of this strength at 45° F. while at 90° F. it would have 117 per cent of its strength at a temperature of 70° F. Obviously, then, the curing temperature is something which must certainly be taken into account in the design of concrete. Cold weather concrete demands a lower water-cement ratio than hot weather concrete in order to compensate for the effect of the low temperature in reducing the compressive strength. The manner in which this compensation might be effected is discussed under the question of concrete design.

Effect of Method of Curing

It has been shown by a number of investigators that the manner of curing concrete plays a most important part in affecting its strength. This fact must be entirely apparent when it is considered that the hydration of the cement continues in the presence of water

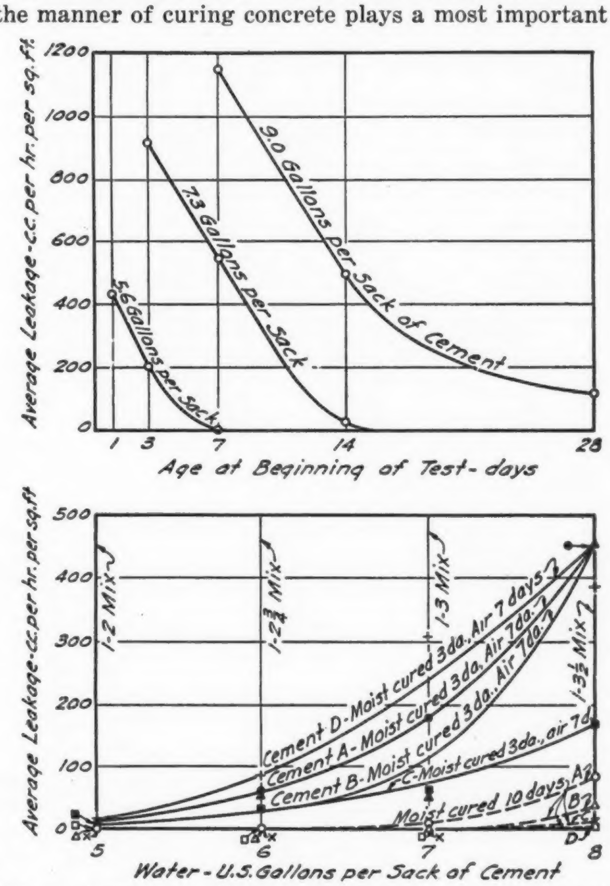

FIG. 7. EFFECT OF WATER CONTENT AND CURING ON PERMEABILITY OF CONCRETE

Six by one-inch cast discs. Pressure, 20 lbs. per sq. in. for 48 hr. Diagram from "The Basic Principles of Concrete Making" by F. R. McMillan

[1] Bulletin No. 81. Influence of Temperature on the Strength of Concrete. University of Illinois Experiment Station.

and stops when there is no moisture present. Moreover, the hydration of the cement results in the combination of additional water with the cement and there-

FIG. 8. RESULTS OF FREEZING AND THAWING TESTS OF MORTAR

fore in the creation of additional solid material within the concrete structure. That this is the case is readily shown by the very marked influence of additional curing on the permeability of concrete. The effect not only of the water-cement ratio but also of the amount of curing is very well shown in Fig. 7. It is to be noted that, as would be expected, the higher the water ratio, the more permeable is the concrete, for reasons which have been previously explained. Moreover, it is seen that although concrete may be quite permeable at an early period it gradually develops a low degree of permeability with age under moist curing conditions. The two most important factors for controlling the permeability of concrete are the water-cement ratio used in the original mix and the degree of curing given to the mix.

It might be thought that the responsibility of the ready-mixed concrete producer ends after he has delivered the concrete to the job and that the kind of curing given is a responsibility to be assumed by the engineer and the contractor. However, if the ready mixed concrete producer is to be entrusted with the design of concrete for a particular purpose, he must take into account all of the conditions to which that concrete is to be subjected and which influence its suitability for the particular purpose intended. Curing plays a most important part in influencing the strength and permeability of concrete and it is highly important that the concrete producer know the kind of curing specified and that he design his concrete accordingly. There his responsibility ends as far as this particular feature is concerned and it is then the responsibility of the engineer and contractor to see that the concrete is cured in accordance with the specifications.

Effect of Proportions on Durability of Concrete

The durability of concrete is influenced by a number of factors among which may be mentioned the soundness of the cement and of the fine and coarse aggregates used, but even when the separate ingredients are perfectly sound there is still the chance of the concrete being non-durable. If we use a high amount of water in mixing the concrete there is bound to be a high percentage of free water in the mixture with a resulting high percentage of pore space in the hardened concrete when this free water evaporates. There is nothing which makes for lack of durability of concrete so much as the use of too much mixing water and by all means is this feature to be guarded against.

A striking illustration of the influence of the mixing water is given in the accompanying Fig. 8 in which are shown the results of freezing tests on Portland cement mortars made in the laboratory of the National Crushed Stone Association using different water-cement ratios and employing a cement and a sand which were both sound. The point to be noticed in the accompanying figure is that the wetter the mixture, the more rapidly has disintegration proceeded.

A Method for the Design of Ready-Mixed Concrete

Having considered the principal factors which control the strength, durability and permeability of concrete we are now in a better position to proceed with the formulation of a method for the design of the particular kind of concrete desired. The method of design which I would advocate as being the simplest and most practical is that known as the method of trial mixtures.

Let it be assumed that we are to design concrete for a given compressive strength. It has been shown that the compressive strength is controlled by a number of different factors, the principal one of which is the water-cement ratio used with the particular cement and aggregates in the mixture. Still another is the kind of curing used; a third involves the temperature at which the curing is given.

Method for the Design of Concrete for a Given Compressive Strength

As seen by the preceding discussion, there are several factors which control the compressive strength of concrete and the producer must know the exact conditions under which the concrete is supposed to attain the strength desired. The most usual condition is that in which the concrete is specified to have the desired strength when moist cured at 70° F. We shall let this condition be known as Case I. The second condition which we shall call Case II is that in which the concrete is supposed to attain a given strength as it is actually cured on the job, the strength in this case being checked by means of job-made and job-cured cylinders.

Case I—Concrete of a Required Strength to Be Produced Under Standard Laboratory Conditions

The first procedure is to establish a water-cement-ratio compressive-strength curve, using the particular

materials employed in the ready mixed concrete plant. This is a laboratory job which should be performed carefully by a laboratory accustomed to this sort of

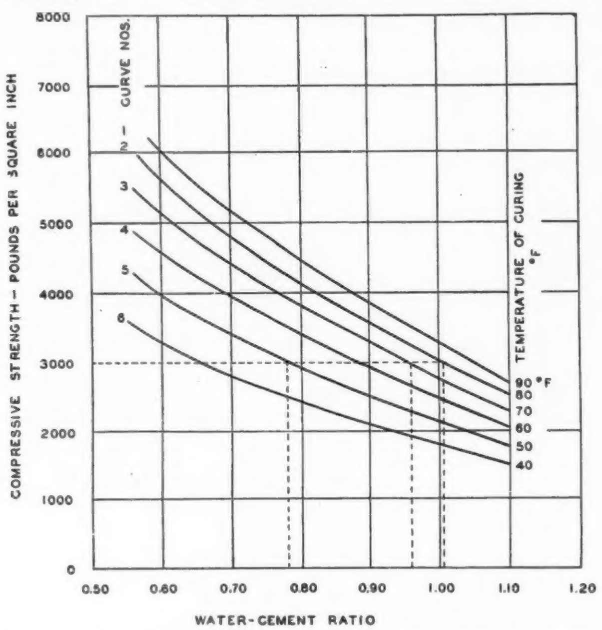

FIG. 9. WATER-CEMENT RATIO—COMPRESSIVE STRENGTH CURVES

work. Let it be assumed that curve No. 3 in Fig. 9 represents the water-cement-ratio compressive-strength curve for any particular material which may be under consideration. From this curve the desired water-cement ratio which will produce concrete of the required strength may be selected. For illustration, if 3000 lb. concrete at 28 days is required, the water-cement ratio needed is 0.96 or approximately 7.1 gal. per sack of cement. The next step consists in determining the proportions of concrete which with this water-cement ratio will give the consistency desired for the job. This is best done by making up trial batches of concrete. In this work the following procedure is used:

First mix up a convenient amount of cement with the quantity of water required by the selected water-cement ratio, in this case 0.96, or 7.1 gal. per bag of cement. Fine aggregate and coarse aggregate are then mixed with this paste, adding these materials cautiously until the right consistency, as required of the concrete, is finally obtained.

For the sake of economy it is desirable to add as much coarse aggregate as possible without sacrificing the necessary workability. If the mixture finally obtained has the right consistency but appears to be too harsh working, this simply means that there is too little sand and too much coarse aggregate and a new trial batch will have to be made in which the amount of sand is increased and the coarse aggregate decreased. Finally by the use of several trial batches of this nature a concrete mixture will be arrived at which has the right water-cement ratio and the right degree of workability for the particular purpose intended. By carefully pre-weighing each of the separate ingredients composing this trial batch, the exact proportions of each of these materials may be obtained and concrete made in these proportions and cured at 70° F. under moist conditions should give very closely the compressive strength desired.

The cement content per cu. yd. of this mixture may be determined very closely by filling a half cubic foot measure with the mixture and obtaining its weight. Knowing the weight of each of the separate ingredients in the batch and knowing the weight of concrete in the half cubic foot measure, the exact weight of each of the materials in the half cubic foot measure may be readily obtained by direct proportion and from this, the exact weight of each of the materials in a cubic yard of the concrete may also be obtained by direct proportion.

Case II—The Proportioning of Concrete to Have a Given Compressive Strength Under Job Conditions of Curing

The ready-mixed concrete producer may be called upon to furnish concrete which will have the required strength under the actual conditions encountered on the job as determined by job-cured and job-made cylinders. The procedure in this case is the same as in Case I but, in addition, the water-cement ratio as determined under Case I must be corrected so that it will give the desired strength under the job conditions of curing. The temperature of curing is a very important factor in affecting the strength of the resulting concrete and under Case II the temperature of curing must be taken into account. This is done by making use of the data shown in Fig. 6.

The procedure is as follows: It will be assumed that we have established the water-cement ratio compressive strength curve for cylinders cured under laboratory conditions, that is, 70° F. in moist air. According to the data given in Fig. 6 we may expect higher strengths at temperatures higher than 70° F. and, correspondingly, we may expect lower strengths when the temperature is lower. Making use of the data in Fig. 6, we may plot water-cement ratio curves for the respective temperatures as shown in Fig. 9 and with these curves in Fig. 9 we are now in a position to determine what water-cement ratio we should use to obtain the desired compressive strength at the expected curing temperature. To illustrate this point let it be assumed that the curing temperature to be expected is 50° F. and that we desire to obtain concrete having a compressive strength of 3000 lb. per sq. in. at 28 days. Referring to Fig. 9 it will be seen that for these conditions we should have to use a water-cement ratio of approximately 0.78 or 5.85 gal. of water per bag of cement. If we expect the curing to be 80° F., it will be seen from the curve that we may use a water-cement ratio of approximately 1.0 for a compressive strength of 3000 lb. per sq. in., or 7½

gal., per bag of cement. Here we assume that the curing actually given on this job will be the same as that given in the laboratory, so far as moisture conditions are concerned and although this condition seldom obtains, nevertheless, there is a saving factor in that concrete specimens are tested in the laboratory generally in a moist condition while the concrete on the job is in a drier condition and hence is actually stronger than the strength shown by wet cylinders. Cylinders tested wet have only about 80 per cent of the strength of the same concrete tested dry.

The Proper Water-Cement Ratio to Use for Different Classes of Structures

It is seen that the water ratio plays a most important part, not only in the compressive strength but in the durability and in the permeability of concrete and hence, it is highly important that the proper water ratio be used for the particular class of structure for which the concrete is being made. Considering all of the accidental variations to which concrete is subjected in its manufacture and curing and considering, in addition, the great variations in exposure, it would be an almost impossible task to set up a set of requirements for water-cement ratio which would meet the exact conditions for any one job. General observation, however, has led to the selection of water-cement ratios, which, in the judgment of experienced observers may be depended upon to give satisfactory results.

TABLE II.—RECOMMENDED WATER-CEMENT RATIOS FOR CONCRETE TO MEET DIFFERENT DEGREES OF EXPOSURE

These requirements are predicated on the use of concrete mixtures in which the cement meets the present standard specifications of the A. S. T. M. and to which an early curing is given that will be equivalent to that obtained when protected from the loss of moisture for at least 10 days at a temperature of 70° F. Also that the concrete is of such consistency and is so placed that the space between the aggregate particles is completely filled with cement paste of the given water ratio.

Exposure / Class of Structure	Water-cement ratio, U. S. gal. per sack *		
	Reinforced piles, thin walls, light structural members.	Reinforced reservoirs, water tanks, pressure pipes, sewers, canal linings, dams of thin sections.	Heavy walls, piers, foundations, dams or heavy sections.
Extreme: 1. In severe climates like in northern U. S., exposure to alternate wetting and drying, freezing and thawing, as at the water line in hydraulic structures. 2. Exposure to sea and strong sulphate waters in both severe and moderate climates.	5½	5½	6
Severe: 3. In severe climates like in northern U. S., exposure to rain and snow, and freezing and thawing, but not continuously in contact with water. 4. In moderate climates like southern U. S., exposure to alternate wetting and drying, as at water line in hydraulic structures.	6	6	6¾
Moderate: 5. In climates like southern U. S., exposure to ordinary weather, but not continuously in contact with water. 6. Concrete completely submerged, but protected from freezing.	6¾	6	7½
Protected: 7. Ordinary inclosed structural members; concrete below the ground not subject to action of corrosive ground-waters or freezing and thawing.	7½	6	8¼

* Free water or moisture carried by the aggregate must be included as part of the mixing water.

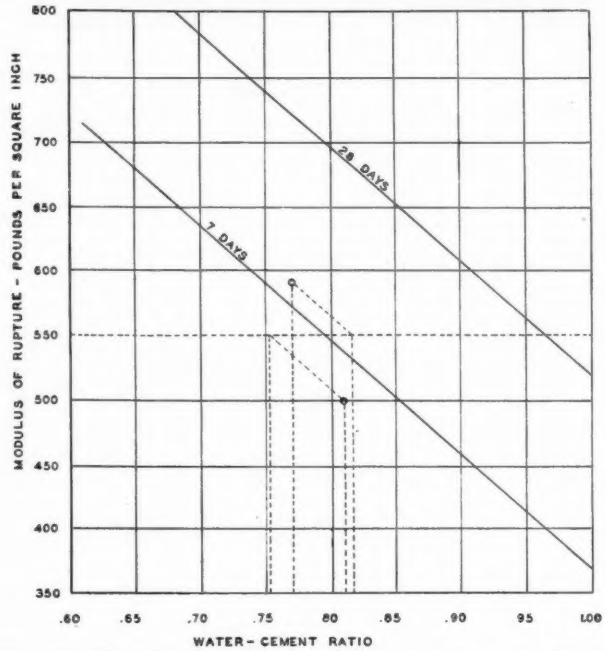

FIG. 10. WATER-CEMENT RATIO—MODULUS OF RUPTURE CURVES

Perhaps no better statement of desirable water-cement ratios for different classes of construction has been made than that by Mr. F. R. McMillan in his book entitled, "The Basic Principles of Concrete Making" from which Table II is taken.

It should be pointed out that these water-cement ratios are the net water-cement ratios available for the hydration of the cement after properly correcting for the absorption of the aggregate or for the free moisture on the aggregates.

Design of Concrete for Its Transverse Strength

Ready-mixed concrete producers may often be required to furnish concrete having a given transverse strength expressed in terms of modulus of rupture. The method for the design of concrete having a given beam or transverse strength is much the same as that used in the design for compressive strength except that we must now work with a modulus of rupture water-cement ratio curve instead of a compressive water-cement ratio curve.

In Fig. 10 is given a curve which shows the approximate relation between modulus of rupture and water-cement ratio. These values were obtained by means of 6 x 6 inch beams tested on a 20-inch span length, using a single load at the center. Here again, we shall use the method of trial batches as our method for the design of the concrete. If we are using the same materials day after day, then beam tests should be made to determine the exact shape of the water-cement

(Continued on page 25)

Development and Carrying Out of a Sales Program Through Central Office Control[1]

By ELWOOD T. NETTLETON
Sales Manager, The Connecticut Quarries Company, Inc. New Haven, Conn.

◆ To obtain the proper relation between production and sales should be the goal of every crushed stone producer. With an industry which is to a large extent seasonable it would seem particularly important to coordinate these two vital factors in economic operation. How one large company is endeavoring to solve this important problem is interestingly described in the following article.

IN any manufacturing business production and sales are the Siamese twins so attached that to separate either from the other means the destruction of both. The production twin within the past few years has grown faster than his brother. Perhaps in some territories there has been over-expansion due to new and more efficient methods of quarrying and crushing and due particularly to the desire to get greater tonnage. Oftentimes the territory has not been analyzed to see whether such added production could be consumed by the market. At any rate most of the quarries are equipped for peak season loads and consequently must run part time the remainder of the year. For these reasons it is the writer's opinion that more food, that is, time, thought and study should be given to the anemic twin, Mr. Sales.

Probably the chief reason for keeping away from open sales discussion is due to reluctance of individual concerns to tell what they believe to be their innermost personal secrets and practices. In every locality throughout America there are producers who play the game of business as true sportsmen—never taking a single unfair advantage—but they demand, and rightfully so, that those who compete in the game with them shall follow the same set rules. We are all too prone to be suspicious and complain about the other fellow without analyzing ourselves.

This reminds me of a man trying to get a divorce. The opposing lawyer questioned him on the witness stand as follows:

"You wish to divorce this woman because she drinks?"

"Yes, Sir."

"Do you drink yourself?"

"That's *my* business!" he replied angrily.

Whereupon the unmoved lawyer asked: "Have you any other business?"

This goes to show that before we complain about others we should clean house ourselves. The day should be here when ethics plays as important a role in our business as it does in legal, medical and other professions.

[1] Presented at the Fourteenth Annual Convention of the National Crushed Stone Association held at the Hotel Jefferson, St. Louis, Mo., January, 1931.

Believing that we shall all benefit by free discussions concerning sales I am taking not only the liberty, but I believe the initiative in placing before you a description of our sales organization, sales methods and even our sales policies.

The Connecticut Quarries Co., Inc., is one of the largest, if not the largest trap rock company in the Eastern United States, producing approximately 800,000 tons annually. In addition to our six quarries we have four company-owned distributing plants and make shipments by truck, trolley, or railroad in four states, namely: Connecticut, Massachusetts, New York and Rhode Island.

Sales Manager

The Sales Department is controlled centrally from the main office at New Haven directly by the Sales Manager who in turn is responsible to the General Manager.

The Sales Manager besides having direct control over advertising, salesmen, service and credit, has the following additional duties: Testing of materials, research, interpretation of specifications, recommendations as to screen ring sizes, study of existing freight rates and proposed changes, establishment of dealers, reports of orders on hand, sizes of material required, expected future tonnage, and special investigations.

Advertising

Perhaps the weakness of our system and in fact with all our producers is that we are inclined to be so engrossed with getting the job away from our competitors that we fail to do as much promotional work, research, and advertising as possible. In this way it might be possible to create additional markets so that we and our competitors may have all we desire.

Besides advertising in commercial and technical publications this company has recently taken moving pictures of their quarry operations as a method of advertising before engineering societies, service clubs, contractors, and public officials. If time is available after the conclusion of this session the speaker will

be pleased to have such films shown, should anyone desire.

A short time ago a pamphlet entitled "Trap Rock" was cooperatively edited by the New Haven Trap Rock Co. and our company. A few copies are here on hand.

Probably the most valuable advertising medium we have struck yet is a series of blotters turned out by us each month and mailed to every person on our mailing list. The cost of these is very small.

Selling

The sales force directly under the Sales Manager comprises three full time salesmen and four distributing bin superintendents, and indirectly six quarry time-keepers who act in a partial sales capacity for local business. We have tried compensation on a sales commission basis, but gave that up and at present all salesmen are on a straight salary basis with a bonus granted by the management at Christmas.

Besides selling, the salesmen collect accounts overdue, and also act as paymasters at the quarries in their territory. This latter fact helps keep the salesmen in contact with the shipping facilities, amount of stone in storage and improvements at the plants.

Each Saturday morning the salesmen report personally to the Sales Manager in the main office. Daily diaries for the past week and calls for the coming week are gone over, credits, unpaid bills, shipments and other matters discussed.

Three days a week the salesmen follow up current special leads, kept by the Sales Manager on a visible card system. These cards are made up from construction jobs proposed to be let or contracted for. Information concerning these is obtained from newspapers, inquiry letters, trade publications and salesmen's hearsay. There is nothing unusual in this part of our program.

However, we believe we have a unique system in what we call our scheduled calls by salesmen. These calls usually consume two days a week with the salesmen making from 4 to 12 calls per day. Before we put in this system we were not positive whether our territory was thoroughly combed. There was no check upon the frequency of calls on a customer. Where the salesman was particularly friendly the calls were often, other prospects were skipped.

After trying this system of scheduled calls for a year and a half, we purposely cut it out for half a year. We found that within a short time the salesmen were back in the old ruts and they themselves have expressed personal desire that the Sales Manager again adopt this system.

Preparatory to adopting this system the following was necessary: First—revise, enlarge and bring up-to-date our mailing list. Second—check names on this list. By sending out advertising matter with sufficient postage all mail matter not delivered was returned with notations such as unknown, out of business, removed, or deceased. Third—cover mailing list by one personal call of salesman. Fourth—determination by salesman as to whether party called on should remain on our mailing list and whether or not he should be placed on our calling list.

All names placed on calling lists were listed in a visible card index system. These cards contain space for name, address, party, date of salesmen's calls, prices quoted, information obtained and shipments made along with a color signal designating the salesmen and a code letter which gives the minimum number of calls a year for this customer.

From these cards and code letters a map was made up with a tab for each city or town. This tab listed the number of A calls, B calls, etc., "A" representing one call per week down to "G" calls representing one call per year. With this map before him the Sales Manager makes up a routing schedule for the year for each salesman. In making this schedule the most economical routing as to distance travelled, length of calls and various seasonal buying habits of each particular client must be taken into account.

This latter fact is rather important with some clients and reminds me of the discussion concerning anniversaries wherein Mrs. Smith asked Mrs. Jones:

"Does your husband remember your anniversary?"

Mrs. Jones' reply was:

"No, he doesn't remember anniversaries, so I remind him of it in January and June and get two presents."

Service

We pride ourselves on our service to our customers and it is our policy to visit all jobs of over 1500 tons before we start shipping and several times throughout the time shipments are being made. These calls are usually made by the Sales Manager.

We do not adopt the policy of the new maid when asked by the lady of the house:

"And is it necessary that I, the lady of the house, should call you in the morning?"

Whereupon the new maid replied:

"I don't has to be called, mum, unless you happens to need me."

We attempt to anticipate any needs or troubles our customers may have and by being familiar with their work avoid any trouble as far as we are concerned. It is said that two-thirds of success in business depends on the proper attention to orders after they are booked and only one third in obtaining new orders. Salesmen only beat competition on a first order, after which time it is an inside job of right prices, high quality material and prompt delivery.

Credit

I am intentionally omitting this item as I feel that

(*Continued on page 24*)

Researches on the Durability of Concrete[1]

By H. F. GONNERMAN
Manager, Research Laboratory, Portland Cement Association, Chicago, Ill.

◆ **The Portland Cement Association has long been recognized as a leader in the field of concrete research. The following article descriptive of investigations recently conducted by them on durability of concrete constitutes a valuable contribution to the literature on this important subject.**

THE DURABILITY of concrete has been given much study by research agencies in an effort to discover the fundamental factors involved in the behavior of concrete under various conditions of exposure and use. The importance of this work is strikingly shown by the many papers which have appeared on this general subject in recent years not only in this country but also abroad. As many of you know, our Research Laboratory at Chicago and our Fellowship at the National Bureau of Standards, Washington, have been engaged for several years in comprehensive investigations on cement, concrete and concrete aggregates. The research programs both at Chicago and Washington are designed to cover as rapidly as possible in order of their importance the many problems which arise in connection with the use of cement and concrete. While many of our earlier researches dealt with strength and other properties, in recent years they have been directed primarily toward such studies as volume change, permeability, fire resistance of concrete masonry units, and durability studies of both cement and concrete. This paper discusses briefly some features of our current durability studies particularly those relating to the part played by the aggregates in the durability of concrete. It is believed these will be of particular interest to you as aggregate producers.

It might be said in passing that to those of us who have long been identified with, or have observed from the outside, the research work of the cement manufacturers, it is very gratifying to note the activities of the aggregate producers in research problems of their own. The solving of problems relating to the durability of concrete should not rest alone on the shoulders of the cement manufacturers even though by their slogan "Concrete for Permanence", they may have invited such responsibility. Aggregate producers must assume some of this responsibility and we interpret this new activity on the part of your organization and the similar organizations representing other aggregate producers as a recognition of their willingness to share this responsibility. It may not be out of place also to point out here that there are still other interests who must assume part of this burden. Perhaps even to a greater extent than either the cement manufacturer or aggregate producer, the architect, engineer and contractor are responsible for the production of durable structures. Although there are many architects, engineers and contractors who have always exhibited great interest in this problem and have realized the importance of good workmanship, unfortunately there are others who have not, for extended field observations and laboratory research have definitely shown that improper workmanship is a far more fruitful cause of unsatisfactory concrete than improper materials.

Durability an Important Property

Of the properties desired in concrete for most of its uses durability is generally recognized as the most important. Producers of aggregates for concrete as well as manufacturers of cement should be vitally interested in the quality of their products for if concrete structures are to endure the materials entering into their fabrication must necessarily be of the proper quality for the particular use intended. Perhaps the most severe conditions to which concrete is exposed are in the relatively thin members of hydraulic structures and in pavements in our northern states and Canada where wide seasonal variations in temperature and moisture conditions occur. To resist such exposures concrete must be of higher quality than would be necessary for similar structures located in the warmer and more equable climate of the southern states.

Although it is true that poor materials are not the most frequent cause of unsatisfactory concrete, there are cases where aggregates are definitely at fault and it is the consideration of such cases that led to this investigation which we are to discuss.

Field Examinations and Laboratory Tests

Surveys of concrete roads and structures in many sections of the United States by our Laboratory and Highways Bureau have disclosed examples of defective concrete which appear to have resulted from the use of either unsound aggregates or of aggregates improperly cleaned and graded. The structures in which the aggregates were unsatisfactory were relatively small in number, and generally restricted to a limited territory, since in most localities there is an abund-

[1] Presented at the Fourteenth Annual Convention of the National Crushed Stone Association held at the Hotel Jefferson, St. Louis, Mo., January 19-22, 1931.

ance of good aggregates, both fine and coarse. Nevertheless in some localities the condition of the structures was such as to warrant careful study of the quality of the aggregates used and their method of production in order to find a solution for the difficulties.

In order to cover all phases of the problem, field examinations of the aggregates at the sources of supply were made and, where possible, information was obtained regarding the performance of structures in which aggregate from a particular pit or quarry was used. Supplementing these field investigations, laboratory tests were made on samples of fine and coarse aggregates directly exposed and when protected by cement-water pastes of varying quality.

The tests applied directly to the aggregates were designed to show the resistance of the particles to wetting and drying, freezing and thawing, heating and cooling and to sodium sulfate action. One of the objectives of these studies was to develop a test by which the durability of aggregates could be readily and positively determined and to establish, if possible, the relations between the behavior of the aggregates when tested alone and in mortar or concrete. Thus far in these investigations about 70 samples of fine and 80 samples of coarse aggregate have been tested. Many of the aggregates were suspected of being responsible, at least in part, for the inferior quality of the concrete in which they were used. While all the tests being made on these aggregates are by no means completed they have developed some significant indications, the outstanding features of which will be briefly pointed out.

Behavior of Aggregates in Soundness Tests

In many instances there was similarity in the behavior of the aggregates when tested alone by the sodium sulfate and freezing and thawing methods although the breaking down of the particles proceeded at a much more rapid rate in the sulfate test. Tests on several samples of fine aggregates showed that to produce equal amounts of failure approximately 3 times as many cycles of freezing and thawing were required as for sodium sulfate. With coarse aggregates the ratio of freezing and thawing cycles to cycles of sodium sulfate for equal amounts of failure was more variable ranging from about 4 to 1 to 10 to 1. There were differences in the manner in which the various coarse aggregates behaved in these tests. Some remained unaffected up to 25 cycles of sodium sulfate treatment. Some broke down gradually by chipping or by splitting apart at laminations, while others broke down almost completely. This shows that when evaluating the results of such tests consideration must be given not only to the amount of failure but also to the manner in which the disintegration of the particles occurs. Failure by chipping, splitting at laminations, or incipient cracks would not be expected to be as serious from the standpoint of durability of concrete as complete disintegration of the particles.

The sodium sulfate test is a severe test and only 5 or 10 cycles were required to produce some failure in most of the aggregates tested. The differences in behavior of some of the samples in this test show that further study is required to determine the number of cycles to be used. From the standpoint of expediency 5 cycles are preferable to a greater number.

Materials which appear to be least resistant to sodium sulfate or to freezing and thawing action are shale, chert, argillaceous limestone (waterlime) and argillaceous sandstone. Of these the shale and chert particles under the conditions of the tests were most detrimental to mortar and concrete and are to be avoided or at least restricted to relatively small amounts. While there are differences in shales, most varieties weather readily and cause pitting and cracking in exposed concrete structures. Cherts are also variable in character. Some varieties break up readily when used in concrete exposed to freezing and thawing and are a frequent cause of popouts.

Mortar and Concrete Tests

To compare the behavior of the aggregates in the direct exposure tests with their behavior in mortar and concrete, several samples of both fine and coarse aggregates representing a considerable range in characteristics were made into 2-in. mortar or 6-in. concrete cubes. These cubes were subjected to alternate freezing and thawing when about 30 days old. To accelerate the action the saturated mortar cubes during freezing were immersed in about ½-in. of water while the 6-in. cubes were submerged. To date the mortar cubes have received approximately 200 cycles and the concrete cubes about 50 cycles of this treatment.

The most outstanding feature of these tests is the very marked influence of the quality of the protecting cement-water paste on the resistance of the aggregates to freezing and thawing in mortar and concrete. When incorporated in a paste of high quality (rich mix of low water content) even those aggregates judged to be relatively inferior on the basis of the soundness tests exhibited a high degree of resistance. On the other hand when a paste of poor quality was used even the best aggregates showed relatively poor performance under the conditions of these tests.

In the case of the fine aggregates, the grading of the particles as well as their other characteristics seemed to have a great influence on the behavior of the mortar cubes when subjected to freezing and thawing. To make a mortar of a given degree of resistance each sand was limited to a definite maximum permissible water-cement ratio. Some of the structurally sound sands, because of their fineness had such high water requirements that they would not make durable concrete if used in the usual arbitrary proportions.

Other of the sands were well graded but actually produced mortars which were lacking in durability because of the structural weakness of many of the particles. Gradings which produced harsh mixtures resulted in mortars having low resistance to freezing due probably to the presence of air and water pockets.

Petrographic Examination

The sands were examined under the microscope and a count made of the suspected non-durable particles each contained. The data thus obtained were compared with the behavior of the sands in the soundness tests and in the mortar cubes. Similarly the behavior of the coarse aggregates in the soundness tests was compared with their behavior in the concrete cubes. It appears that the most injurious of the non-durable materials is shale. Shale when present in sands in quantities greater than about 3% produced a mortar having relatively poor resistance to freezing even though the sands were well graded. Some sands were found to contain as much as 30% of shale.

Relation of Direct Soundness Tests to Mortar and Concrete Tests

Thus far no definite relationship has been found between the results of soundness tests on aggregates alone and their behavior upon exposure to alternate freezing and thawing in mortar or concrete. In other words, it is not possible to predict definitely the behavior of an aggregate in concrete or mortar from its behavior in the sodium sulfate or the freezing and thawing soundness test. It appears that much depends on the physical structure and mineralogical composition of the aggregate tested. Some fine aggregates judged to be relatively inferior on the basis of the sodium sulfate soundness test when made into 2-in. mortar cubes and protected with a cement paste of good quality have withstood as many as 140 cycles of freezing and thawing without showing appreciable failure. On the other hand if given the poor protection of an inferior paste, rapid disintegration occurs. The grading of the particles because of its effect on water requirements, as well as the kind and extent of curing and other factors also has an important influence on the durability of the resulting mortar or concrete.

While there is some uncertainty as to the significance of direct exposure soundness tests in judging the concrete-making properties of aggregates, they are of value in detecting structural weaknesses in aggregate materials which under some conditions may seriously affect the durability of the concrete in which they are used. It is conservative to look with suspicion on those materials showing relatively poor results in the sodium sulfate test, until such time as it is proved that they are suitable for use.

Specification Requirements for Durability of Aggregate

Specifications for concrete aggregates generally require that the particles consist of hard, strong, durable pieces. In some of the more recent specifications of our national technical societies limits have been set for the amounts of deleterious substances and in the case of coarse aggregates the testing of the particles for durability by either the sodium sulfate or freezing and thawing methods is specified. From the information now available it is difficult to set limits for the amount of failure to be permitted in such tests since the quality of the concrete as a whole as well as that of the aggregate itself has an important bearing on the performance of concrete structures. A permissible loss of 15 to 20% by weight at 5 cycles in the sodium sulfate test has been suggested for coarse aggregates and 10 or 12% for fine aggregates. These values appear to be reasonable in the light of our present knowledge. However, in fixing limits for specification purposes the important factors to be considered are first the quality of the concrete in which the aggregate is to be used and the type of exposure to which it will be subjected, and second the character of the unsound material. As pointed out above it has been our experience that shales, similarly laminated materials, and some of the cherts are the most undesirable and hence should be permitted in only small amounts. The service record of an aggregate over a period of years also should be taken into account in determining whether it is suitable for the production of durable concrete. But in fairness to the material producer, care must be taken to distinguish between poor performance due to improper workmanship and poor performance due to faulty materials, a distinction which is not always easy to make.

Cleanliness

Besides the question of soundness there is another important factor which should not be overlooked in the preparation of aggregates for durable concrete and that is their cleanliness. The producer should not only aim to have a durable product but also a clean one. Examinations of pits and quarries in certain localities showed that some plants do little, if any, stripping but attempt to remove silt, loam and clay at the washing plant. It has been our experience that the so-called crusher dust is frequently the overburden which during wet weather adheres to the particles. Dirty and coated aggregates are to be avoided as they probably have a much greater effect on the durability of concrete than clean aggregates containing relatively small amounts of unsound materials.

It may be of interest to point out that of 24 samples of crushed stone aggregate tested in one part of this general investigation only 3 were judged to be lacking in durability. These latter contained waterlime, fine grained argillaceous sandstone and shale, or bitumin-

ous shale limestone. The products of some quarries examined were found to contain much flint or chert which in sizes larger than about 1½ in. may be troublesome since they lead to the production of pop-outs and scaling of the mortar with which they do not form a good bond, especially in over-wet mixes. The lack of bond permits the penetration of water and thus promotes failure by freezing.

Summary

In conclusion the most significant indications thus far from our tests and observations may be briefly summarized as follows:

The most important factor affecting the durability of concrete is the quality of the cement-water paste which provides protection to the aggregate. Improper grading, improperly proportioned mixtures, improper curing, and dirty material are important factors which affect the quality of the paste and therefore the durability of the concrete. However, for the severest exposures some materials require a better quality of protective paste than others, while some, especially those containing readily weatherable shale, are so harmful as to make their protection impossible or impractical and they should therefore not be used. Soundness tests made directly on the aggregate serve to indicate the possibilities of the material but as yet cannot be taken to definitely measure its ability to produce a permanent concrete.

The responsibility of the aggregate producer in the attainment of durable concrete is to see that his product is clean, properly graded, and reasonably free from those materials which have been pointed out as likely to be harmful. The responsibility of the cement manufacturer is to furnish cement of the proper quality. Given satisfactory materials it is then the responsibility of the architect, engineer and contractor to obtain such quality of workmanship in the manufacture of the concrete that its permanence under the given conditions of use will be assured.

Twenty Foot Highways Minimum Recommended by Road Builders

ROAD widening to a minimum of 20 feet is recommended in states and counties in a committee report of the American Road Builders' Association by C. E. Burleson, county highway engineer, Clearwater, Fla., chairman of the committee on road widening. Recommendations are also made as to when and how roads should be widened.

"The population in urban and suburban sections has grown so rapidly, and such a large percentage of the people own automobiles that the widening of old roads must be carried forward rapidly," declared Mr. Burleson.

Future traffic demands as to width of pavement should be anticipated for ten years, the committee says, and right of way should be wide enough for conditions 25 years hence. Highways for two lanes of traffic should be paved at least 20 feet wide with 6-foot shoulders for parking. Intersections should be widened to four traffic lanes (40 feet) for 300 feet in each direction from the corner. Where traffic exceeds 4,000 vehicles a 10-hour day, or frequent peak loads in excess of 800 vehicles an hour in one direction exists, a three or four lane road is needed. The salvage value of the old pavement should be sacrificed to improve the alignment or to provide clearer vision over hills.

In widening an old pavement, a narrow but substantial widening strip even with the old surface on both sides improves the appearance of the road, gives definite limits for pavement maintenance, and guides traffic. A few feet added to one side is less expensive than widening both sides, but the new track of vehicles may change the heavy loads to a weak point on the pavement.

Pavements on curves, comments the committee, should be given from one to six feet extra width, and they should be marked down the center to separate traffic.

"Based on facts collected from numerous states and counties, the committee lays down rules for road widening which, while not ironclad, give a concensus of engineering opinion as to when and how the work should be done," stated Chas. Grubb, engineer executive in charge of fact collection.

April Highway Contracts Increase

SHARP increases in State highway construction contracts let in April were shown today (May 23) in reports announced by Fred C. Croxton, vice chairman of the President's Emergency Committee for Employment.

A report from W. C. Markham, executive secretary of the American Association of State Highway Officials, showed that 40 States let contracts in April for a total of 7,296 miles of roads at a total contract price of $96,879,468. This includes State and Federal-aid roads.

"This amount is at least twice the amount contracted for in the month of April last year," Mr. Markham said. "It does not include contracts made for bridge construction, which total several millions of dollars, but covers only road work."

In addition, a report from Thomas H. MacDonald, chief of the Bureau of Public Roads, showed $8,178,007 worth of Federal-aid contracts let in April in seven States not included among the 40 reported through Mr. Markham. This makes a grand total of $105,057,475 worth of contracts reported.

The total number of workers employed on roads in the group of 40 States during April, according to Mr. Markham's report, was 193,907.

In March, 34 States let contracts for a total of 5,642 miles of roads at a total contract price of $79,917,725. In that month the total number of workers on roads in those 34 States was approximately 192,000.

Many N. C. S. A. Members Win Recognition in National Safety Competition

THE remarkable growth of the safety movement in the mining and allied industries is again demonstrated by the awards made to a large number of mines and quarries participating in the National Safety Competition for 1930 in recognition of the long-time operation of their properties with no accidents or with decidedly low accident rates. The National Safety Competition is conducted annually by the United States Bureau of Mines, Department of Commerce. In letters addressed to the companies receiving trophies and to those given honorable mention, Scott Turner, Director of the Bureau of Mines, states that an annually increasing number of companies are succeeding in operating their properties with unusually favorable records in the prevention of accidents. The National Safety Competition, he stated, is proving a very effective safety movement largely because its competitive features have a strong appeal both to mining companies and their employees.

More than 300 large operations participated in the competition during 1930. Seventy-two of these went through the year without a single lost-time accident. Contestants were divided into 5 groups, 4 of them comprising underground operations, as follows: Anthracite, bituminous coal, metallic ore, and nonmetallic mineral; and the fifth including quarries or open-cut mines. A replica of the bronze trophy, "The Sentinels of Safety," donated by *The Explosives Engineer* Magazine, was awarded to the winner in each group.

* * *

The winner in the quarry and open-cut mine group was the Plymouth iron mine of the Plymouth Mining Co., Wakefield, Mich., which worked 382,541 man-hours without a lost-time accident.

The following-named operations in this group, which worked the number of man-hours below set forth, operated without a lost-time accident:

Wakefield iron ore mine, Wakefield Iron Co., Wakefield, Mich., 331,367.
LaSalle limestone quarry, Marquette Cement Mfg. Co., LaSalle, Ill., 296,997.
*Cape Girardeau limestone quarry, Marquette Cement Mfg. Co., Cape Girardeau, Mo., 224,514.
Dunwoody iron ore mine, Orwell Iron Co., Hibbing, Minn., 218,035.
Columbia Division limestone quarry, Pittsburgh Plate Glass Co., Zanesville, Ohio, 189,751.
*Holston limestone quarry, American Limestone Co., Mascot, Tenn., 174,653.
Albany iron ore mine, Crete Mining Co., Hibbing, Minn., 165,875.
Sagamore iron ore mine, Sagamore Mining Co., Ironton, Minn., 165,058.
Mahnomen iron ore mine, Cuyuna Ore Co., Ironton, Minn., 164,196.
Ormrod cement rock quarry, Lehigh Portland Cement Co., Ormrod, Pa., 164,193.

* Member National Crushed Stone Association.

Mason City limestone quarry, Lehigh Portland Cement Co., Mason City, Ia., 158,814.
*Rock Hill trap rock quarry, General Crushed Stone Co., Rock Hill, Pa., 157,633.
Bennett iron ore mine, Bennett Mining Co., Keewatin, Minn., 145,871.
Fogelsville limestone quarry, Lehigh Portland Cement Co., Fogelsville, Pa., 145,790.
*Spore limestone quarry, National Lime and Stone Co., Spore, Ohio, 143,000.
*Nos. 5 and 6 limestone quarries, North American Cement Corp., Martinsburg, W. Va., 141,706.
Chanute limestone quarry, Ash Grove Lime and Portland Cement Co., Chanute, Kansas, 133,993.
Petoskey limestone quarry, Petoskey Portland Cement Co., Petoskey, Mich., 132,725.
Dewey limestone quarry, Dewey Portland Cement Co., Dewey, Okla., 126,401.
No. 3 limestone quarry, Pennsylvania-Dixie Cement Corp., Richard City, Tenn., 118,089.
Biwabik iron ore mine, Biwabik Mining Co., Biwabik, Minn., 114,765.
*Holland limestone quarry, France Stone Co., Maumee, Ohio, 104,183.
Hercules cement rock quarry, Hercules Cement Corp., Stockertown, Pa., 100,611.
Birmingham limestone quarry, Lehigh Portland Cement Co., Tarrant City, Ala., 100,320.
Greencastle limestone quarry, Lone Star Cement Co. Indiana, Inc., Greencastle, Ind., 99,712.
Clinchfield limestone quarry, Pennsylvania-Dixie Cement Corp., Clinchfield, Ga., 99,423.
*Security limestone quarry, North American Cement Corp., Security, Md., 98,048.
El Paso limestone and shale quarry, Southwestern Portland Cement Co., El Paso, Texas, 95,748.
Fordwick limestone quarry, Lehigh Portland Cement Co., Fordwick, Va., 94,560.
*Jamesville limestone quarry, General Crushed Stone Co., Syracuse, N. Y., 92,723.
Cement Mill limestone quarry, Lawrence Portland Cement Co., Thomaston, Me., 91,842.
No. 4 cement rock quarry, Alpha Portland Cement Co., Martins Creek, Pa., 87,339.
Nazareth cement rock quarry, Nazareth Cement Co., Nazareth, Pa., 85,224.
Sandt's Eddy cement rock quarry, Lehigh Portland Cement Co., Sandt's Eddy, Pa., 81,795.
*No. 2 limestone quarry, Southwest Stone Co., Chico, Texas, 79,442.
Dallas limestone quarry, Trinity Portland Cement Co., Dallas, Texas, 75,362.
LaSalle limestone quarry, Alpha Portland Cement Co., LaSalle, Ill., 74,844.
Iola limestone quarry, Lehigh Portland Cement Co., Iola, Kansas, 73,728.
Bonneville cement rock quarry No. 1, Lawrence Portland Cement Co., Northampton, Pa., 73,431.
*North Baltimore limestone quarry, France Stone Co., North Baltimore, Ohio, 69,776.
Mitchell limestone quarry, Lehigh Portland Cement Co., Mitchell, Ind., 69,536.
Catskill limestone quarry, Alpha Portland Cement Co., Cementon, N. Y., 62,245.
Dixon limestone quarry, Medusa Portland Cement Co., Dixon, Ill., 59,881.
*Ridgeville limestone quarry, Mid-West Rock Products Corp., Ridgeville, Ind., 59,231.
Concrete limestone quarry, Superior Portland Cement Co., Inc., Concrete, Wash., 58,972.
*Spencer limestone quarry, Mid-West Rock Products Corp., Spencer, Ind., 54,909.
Oglesby limestone quarry, Lehigh Portland Cement Co., Oglesby, Ill., 54,312.
No. 7 limestone and shale quarry, Pennsylvania-Dixie Cement Corp., Portland Point, N. Y., 52,610.
*Kenneth limestone quarry, France Limestone Co., Logansport, Ind., 52,307.

*Rocky Hill trap rock quarry, Connecticut Quarries Co., Inc., Rocky Hill, Conn., 47,405.

Alpha limestone quarry, Alpha Portland Cement Co., Alpha, Mo., 47,262.

Richmond iron ore mine, Richmond Iron Co., Palmer, Mich., 46,151.

No. 4 cement rock quarry, Pennsylvania-Dixie Cement Corp., Nazareth, Pa., 45,916.

Mildred limestone quarry, Consolidated Cement Corp., Mildred, Kansas, 45,600.

*Howes Cave limestone quarry, North American Cement Corp., Howes Cave, N. Y., 44,530.

New Castle limestone quarry, Lehigh Portland Cement Co., New Castle, Pa., 41,580.

*Mt. Carmel trap rock quarry, Connecticut Quarries Co., Inc., Mt. Carmel, Conn., 40,522.

Trident limestone quarry, Three Forks Portland Cement Co., Trident, Mont., 37,141.

Bonner Springs limestone and shale quarry, Lone Star Cement Co. (Kansas), Bonner Springs, Kansas, 34,134.

Medusa limestone quarry, Medusa Portland Cement Co., York, Pa., 31,728.

State Hospital limestone quarry, Rochester State Hospital, Rochester, Minn., 31,200.

Fredonia limestone quarry, Consolidated Cement Corp., Fredonia, Kansas, 30,114.

The following-named acted as members of the Committee on Award:

James F. Callbreath, Secretary, American Mining Congress.
W. H. Cameron, Managing Director, National Safety Council.
A. J. R. Curtis, Assistant to the General Manager, Portland Cement Association.
A. T. Goldbeck, Director, Bureau of Engineering, National Crushed Stone Association.
William Green, President, American Federation of Labor.
C. B. Huntress, Executive Secretary, National Coal Association.
T. T. Read, Professor of Mining, Columbia University.

Motor Vehicle Registrations and Fees Increase Slightly

REGISTRATIONS of passenger motor vehicles for 1930 showed a decrease from the 1929 figures, but motor truck registrations increased enough to make a slight gain of 0.08 per cent in total motor vehicle registrations for the year, according to reports of the 48 States and the District of Columbia to the Bureau of Public Roads, U. S. Department of Agriculture.

Registered automobiles, taxis and buses numbered 23,042,840 for the year, a decrease of 78,749 vehicles from the 1929 figures of 23,121,589; the registration of 3,480,939 motor trucks and road tractors showed a gain of 101,085 over the 1929 figures. The total registration of passenger vehicles and of motor trucks for the year amounted to 26,523,779, as against 26,501,443 in 1929.

The States and the District of Columbia collected in registration fees, licenses and miscellaneous taxes in 1930 a total of $355,704,860, which is $7,861,317 more than they collected in 1929. The revenue included fees on passenger cars and buses, on trucks and tractors and on trailers and motorcycles; also dealers' licenses, chauffeur and operator permits, and miscellaneous receipts.

In addition to passenger vehicle and motor truck registrations, 41 States reported a registration of 262,507 trailers, which is a gain of 69,463, or more than 36 per cent over the 1929 figures. This gain in trailers is the largest made in any one year as compared with a previous year since the Bureau began to compile detailed registrations in 1921. The motorcycle registrations of the 48 States and the District for the year amounted to 107,811, a decrease of 7,034 from the previous year's figures.

An eastern and a western State, New York and California, each report more than two million passenger vehicles and motor trucks registered in 1930. Each of five States, Illinois, Michigan, Ohio, Pennsylvania and Texas, report more than one million registered.

After deducting $19,196,926 for collection and administration expenses and $9,473,671 for miscellaneous items provided by various State laws from the total revenue collected of $355,704,860, the States apportioned the remainder to the construction and financing of State and local roads in the following amounts; $222,146,682 for State roads; $68,577,899 for local roads; and $36,309,682 was applied to State and county road bond indebtedness. Some of the purposes for which the miscellaneous funds were spent included refunds stipulated by law, State highway patrol, city streets, and general funds of cities and States.

Making Use of Large-Size Aggregate[1]

HIGHWAY engineers seem to be taking the lead in utilizing the advantages of large-size coarse aggregate, although in the construction of dams the same practice prevails.

In letters addressed to *Concrete* a number of highway engineers have reported favorable experience with large aggregate. In most instances the coarse material is separated into two sizes—for example, from 1/4 to 1 1/2 inches and from 1 1/2 to 3 inches.

One advantage found in the use of two sizes of coarse material is the better grading, for this practice insures the presence of all particle sizes between the smallest and the largest size limits. This condition, in turn, insures a low void content, which leads directly to the second advantage of greater density along with increased yield.

In cases where aggregate from local pits is employed on important construction work, good practice requires the pit-run material to be screened and then recombined in the proper proportions between the fine and the coarse. Too often, however, the sizes above 2 inches are discarded. This is clearly a wasteful practice, since the larger sizes can be employed to advantage in all parts of the structure that are not heavily reinforced.

[1] Editorial appearing in *Concrete* for May 1931.

« « THE PRESIDENT'S PAGE » »

The Research Advisory Committee

YOU were informed through the editorial pages of the March issue of *The Crushed Stone Journal* of a plan which will provide a fund to be used solely for increasing the research work of our Bureau of Engineering.

It has become apparent that we are also in need of some method by which the Bureau of Engineering can keep in closer touch with the membership between conventions, and be more helpful to those not requiring individual service. Practically all of the work which is being done by our Bureau is, in its final analysis, concerned with the marketing of crushed stone. Mr. Goldbeck, through travel and correspondence, becomes acquainted with some of the sales problems and, by his familiarity with our product and its uses, is able to recognize numerous possibilities for further use of crushed stone. To obtain a complete and comprehensive knowledge of the problems facing the industry, and to intelligently and accurately judge of their relative importance, some means should be provided for frequent discussion between the Director of the Bureau of Engineering and those engaged in the production and sale of crushed stone.

The way to properly and adequately fill this need seems to be by means of a committee. This committee will necessarily be exceedingly active and its members selected for their individual knowledge of and participation in:

1st— Local Conditions
2nd—Sales Problems
3rd—Plant Operation
4th—Research work carried on by other laboratories.

The next step was to appoint such a committee and find the person capable and willing of assuming the responsibilities of Chairman. Following is the personnel of the committee to date, with further appointments contemplated:

P. B. Reinhold, Chairman	G. E. Martin
Max Altgelt	C. A. Munson
O. G. Berger	H. O. Olson
H. E. Billman	A. S. Owens
J. N. Bohannon	John Prince
L. C. Bonnell	Russell Rarey
F. O. Earnshaw	B. P. Rex
R. E. Fowle	J. A. Rigg
C. E. Glassen	A. R. Taylor
R. G. L. Harstone	W. C. West
F. S. Jones	T. I. Weston
Dr. H. F. Kriege	R. C. Yoeman

It is my request to the Chairman of the committee that meetings be held frequently as it is possible to gain a thorough knowledge of the work of the Bureau and the needs of the industry only through constant study and discussion. As it will be impossible for the entire committee to meet each month, all members should receive a copy of the agenda of the meeting and subsequently a report of its discussion, recommendations and transactions. If such a procedure is adopted it will enable each member to consult and advise with the Chairman by letter.

Certain duties and responsibilities seem to me to belong to such a committee and additional ones will naturally become apparent as the committee work develops. A few of these I had in mind when considering the need for this committee are as follows:

1. To thoroughly canvass the research needs of the Association for the purpose of advising the President and Board of Directors of the problems which are in most urgent need of research or attention of the Bureau of Engineering.
2. To advise the President and Board of Directors of the nature of engineering literature which should be published by the Bureau of Engineering.
3. To review the research reports of the Director of the Bureau of Engineering and the results of the research investigations of the Bureau as they become available, for the purpose of making helpful suggestions to the Director of the Bureau of Engineering.
4. To help the President and the Board of Directors encourage closer cooperation between the Bureau and the membership by better acquainting the latter with the work of the former.
5. To assume the duties of former committees having to do with Simplification of Sizes, Standardization of Equipment, Elimination of Dust, Ballast, etc., making recommendations to the Association regarding these special problems.

I consider we are extremely fortunate that Mr. Reinhold has consented to accept the chairmanship of this committee, and I am confident that under his able guidance the committee will be able to suggest to the President and Board of Directors some means by which the efforts of the Bureau of Engineering and

the results of its research work may be used to greater advantage by the members of the Association.

About Price Cutting

It has been my pleasant duty recently to attend the regular meetings of two local associations. A meeting of the New England Crushed Stone Association was held at Boston, Massachusetts, on April 24, 1931, and the New York State Crushed Stone Association meeting was held at Syracuse, New York, May 1, 1931.

At both of these meetings I listened to and took some part in the discussion of problems of vital importance. There seems to be a serious epidemic of "Quarryman's hysteria" which is so apt to break out in the early Spring and results in "price cutting." What a blessing it would be if we could only realize that this disease is self-inflicted, extremely contagious, and can be cured in only one way. "Price cutting" is stopped when producers stop cutting prices.

If I may offer a word of advice at this time it would be to remind you not to lose sight of the fact that most operators have increased their production capacity from 50 to 100% in the past five years, that railroads in general have curtailed their ballast purchases this year, and that no one can expect to make up this loss of ballast by seeking more than his share of commercial business.

1930 Gasoline Tax $494,683,410

THE gasoline tax yielded a net revenue of $494,683,410 in 1930 and nearly fifteen billion gallons of gasoline were used by the motor vehicles of the United States, according to reports received by the Bureau of Public Roads of the U. S. Department of Agriculture from State agencies.

As compared with 1929, the tax revenue increased 14.6 per cent and the consumption of gasoline increased 3½ per cent in spite of the fact that there was no increase in the total number of motor vehicles. The average consumption per vehicle was 556 gallons in 1930 as compared with 538 gallons in 1929.

A gasoline tax was imposed in all the States, the rate ranging from 2 to 6 cents per gallon. The average rate was 3.35 cents per gallon. The net revenue of $494,683,410 was allocated as follows: $1,102,187 for collection expenses; $338,927,564 for State highways; $96,225,637 for local roads; $20,869,901 for State highway bond payments; $10,179,135 for local road bond payments; $11,842,930 for city streets; $13,404,200 for schools, and $2,131,856 for miscellaneous expenditures.

The average of the annual registration fees is $13.41 and this added to the average gasoline tax of $18.62 made a total direct tax on the motorist of $32.03. These two taxes formed the largest item of revenue for highway purposes.

An analysis by the bureau shows that the average consumption of gasoline per motor vehicle was 452 gallons in 1925 and there has been an increase each year to 556 gallons in 1930. This increase is thought to be the result, in part, of the increased percentage of trucks and other commercial vehicles but it has also been influenced by increased use of the average vehicle.

A GROUP of leading financial statisticians—experts in forecasting business—met in New York City on November 4. This is what eight of these experts said:

1.—"The farmers will not buy much from the proceeds of this harvest; and, with the price declines in process throughout the world, there would seem to be little prospect of any extensive business revival in the near future."

2.—"The general prospect is for slow and irregular business for ten years."

3.—"I expect to see a long and slow recovery to a general level of sub-normal, slow business."

4.—"Prices will advance a little from present levels and then fall once more. Recovery will be slow."

5.—"Conditions abroad will continue to affect our business conditions here. It is a conservative estimate to say that ten years must elapse before we can see genuinely prosperous business in this country."

6.—"Business will come back to fair, slow operations in three years."

7.—"The period of readjustment will be long. It will take at least ten years."

8.—"We may expect a slow return to a basis in which business can be done at a profit in about three years."

These pessimistic forecasts were all made on the 4th of November. *But it was the 4th of November of the year 1921.* At that time, business was actually improving, although the experts did not know it. Within four months, the gain was so marked that everybody could see it. Within sixteen months, business was so far above normal that experts became frightened again.

Today the major economic factors are more favorable to rapid recovery of business than they were at the close of the year 1921.—*Exchange.*

Smart Fellers

A lady motorist was driving along a country road when she spied a couple of repairmen climbing telephone poles. "Fools," she exclaimed, "they must think I never drove a car before!"—*The C. and P. Call.*

« « EDITORIAL » »

"Useful Information"

THE Association, through its Bureau of Engineering, has recently established a new service exclusively for members, which has been designated as "Useful Information." That the salesmen of the industry should be more thoroughly acquainted with the fundamental principles involved in the various uses of crushed stone has long been realized, and it is primarily to accomplish this that the new service has been inaugurated, although there will also be included much that should be of value and interest to the executives. At frequent intervals, probably once a week, there will be sent out a mimeographed article on a subject of specific interest to the crushed stone industry. Some idea as to the scope of the material which will be released can be gained from the following general headings:

Physical Properties of Stone
Concrete
Railroad Ballast
Macadam Type Roads
Sewage Disposal

When it is realized that many articles will be written under each of these heads, some appreciation of the valuable assistance which this service will render should be obtained.

What is specific gravity? How is the term used in connection with the crushed stone industry? If you know that a cubic yard of crushed stone weighs 2,600 pounds and that the stone has a specific gravity of 2.68, can you determine the solid volume of stone in the cubic yard? You may perhaps wonder why you should wish to have that information, and in reply—the average crushed stone salesman has no doubt many times been asked to determine the volume of concrete produced by given quantities of material. The answers to such questions will be clearly and simply given in "Useful Information."

Any really competent salesman must be thoroughly familiar with the product which he sells. This is certainly no less true with regard to the crushed stone industry. The crushed stone salesman who has a clear and thorough understanding of the principles involved in the various uses of crushed stone, who realizes its advantages as well as its limitations and the reasons therefor is certainly the possessor of a distinct advantage over those of his fellow salesmen not so fortunately equipped.

In inaugurating this service there has been sent to each member company with the first article an attractive loose-leaf binder labeled, "Useful Information," and the articles as released will be given convenient reference numbers for ease in filing. To date four articles have been sent out under the titles:

Specific Gravity
Solid Volume and Voids
Fundamental Conceptions of Concrete
Allowable Quantities of Mixing Water for Concrete Under Different Exposure Conditions

No matter how valuable or how great the need, no information given out by the Association is worth the paper it is written on, to say nothing of the cost involved in its preparation, unless it is used. Our responsibility lies in providing the membership with truly valuable information, but the members themselves have an equal responsibility in seeing that such information is used to the fullest possible extent.

In inaugurating this service the first release and binder was sent to each member company of the Association with the specific request that the Washington Office be immediately advised as to additional names which members desired to have placed on the mailing list to receive binders and subsequent releases. The quick and enthusiastic response to this request was most gratifying, but there are still apparently many member companies which have not appreciated the advantages of having their salesmen regularly receive this information as it is sent out. To direct attention to the value which many members feel will be derived from this service, we wish to quote from some of the letters which have recently been received.

One company writes, "This is indeed especially useful information to us and I like the binder, for it not only keeps papers in proper shape but is in such portable form that it fits into my pouch so as to always be on hand when needed."

Another member says, "I believe this will grow into one of the most useful services of the Association."

The following is a particularly significant comment, "The outline of the proposed articles constitutes an instructive course of study in which all of us should be interested and which should prove of value, not only to executives and salesmen but also to operating men as well."

"This is one of the best steps, in our estimation, that the Association has taken and we want you to know that it is very much appreciated," writes one of the members of the Executive Committee.

Obviously the time and effort involved in the preparation of this material for distribution is essentially the same whether we have two hundred or five hundred

names on our mailing list. Many companies have already requested that the material be sent to all of their salesmen and in some instances we have been asked to send it to plant superintendents. As stated in the letter which went with the first article, no charge will be made for this service. For those companies desiring to receive more than one copy, it is essential that they advise the Washington Office as to the additional names which should be placed on our mailing list.

"Useful Information" should be regularly received by each and every salesman of all member companies. We clearly recall that at the session for salesmen at one of our annual conventions, the suggestion was made that a service of this type be established. The service is now available but to be completely effective your cooperation is essential. Will you immediately advise the Washington Office, if you have not already done so, that your name should be placed on the mailing list to receive "Useful Information?"

Development and Carrying Out of a Sales Program Through Central Office Control

(*Continued from page 14*)

my personal friend, Mr. Hilliard, the next speaker, will cover this important subject very completely and in a better manner than I could. The subject, however, always reminds me of the joke wherein a contractor in making up his will named six material men as pallbearers. When questioned by his lawyer as to the reason he replied:

"They have carried me throughout life, so they might just as well finish the job."

There is no doubt that too many of us material men are assuming the role of bankers.

Sales Policies

Due to our centralized control over sales it is possible for us to adhere strictly to the sales policies of the management.

We believe in and have tried to maintain standard published prices. Most cases where we have lowered our figures have been to compete with a proposed local crusher set up by a contractor. When our prices were lowered it was to all bidders alike. Secret discounts have never been granted. Suppose we, the larger producers, to even a small extent make price a matter of individual bargaining. Is it not reasonable to expect that the smaller and weaker companies will do the same? As a result the purchaser will never know whether he is getting the bottom price and always expects some other purchaser may be getting a better deal from us. Thus selling becomes a matter of bartering. The various producers then put too much belief in customers' statements as to competitors' prices. This invariably forces prices down to un-

profitable levels with a slim chance of getting them back to a fair normal price.

The marketing of our surplus stock outside of our regular territory at reduced prices (known as dumping) has never been practiced. The economic effects of dumping can be seen only when we consider industry as a whole. Dumping is in fact a form of price cutting and invites retaliation. Even though there may be no direct retaliation regular customers will soon find out and expect the same low prices.

We have never paid any public officials, purchasing agents or others (not connected with our concern), to complete any sales or future sales. In no case have large sums of money been spent on excessive entertainments.

Summary

In presenting this paper I do not claim our sales program to be perfect or that it would fit all other producers' needs. Any sales program at best must be flexible and constantly subject to readjustment. Many changes have affected us in the last few years. Distances of truck deliveries have increased, freight rates have been reduced, transit mix has proven its value, specifications have been revised.

It is possible that heavier primary road systems, large mileage of secondary road systems, sewage works, aviation runways and more rigid building laws may create variable and greater demands for our products. Perhaps our real competitor is not our present acknowledged competitor of today but the competitor of tomorrow. The real competitor is changed. By pulling together we shall be stronger to take advantage of what the future may have in store for us.

The Proportioning of Concrete for Strength, Durability and Impermeability

(*Continued from page 12*)

ratio-modulus of rupture curve. With this curve available, we would then be in a position to merely make up trial batches of concrete, using the water-cement ratio required to give the desired modulus of rupture as read off directly from the curve. The proper proportions of fine and coarse aggregates would be determined by trial batches just as was described in the case of the compressive strength, that is, a paste of neat cement would first be made up to the proper water-cement ratio, then the fine and coarse aggregates would be added to this paste and mixing continued until exactly the right consistency is obtained and the right ratio of fine to coarse has been determined for proper workability.

A semi-rational way for arriving at the proper ratio of fine to coarse aggregate for use in beam testing was described by the writer in the March, 1930, issue of

The Crushed Stone Journal. The details of this procedure will not be entered into here.

Suppose it is desired to find the proper proportions of concrete and proper water ratio to use in the absense of a complete water ratio curve for the particular materials being used. For this purpose the curve in Fig. 10 will be helpful. It will first be necessary to mix up concrete using a water ratio arrived at by judgment and presumed to give somewhere near the desired modulus of rupture. The proper ratio of fine to coarse aggregate will be determined by a trial batch, adding as much coarse aggregate as possible for the sake of economy and yet not too much to destroy the necessary workability. At the end of the desired test period, for illustration 7 days, a beam test must be made to determine the strength of our trial mixture.

Let us suppose that we desire to determine the proportions of concrete which will give a modulus of rupture of 550 lbs. per sq. in. at 7 days. Let us further assume that the beam strength obtained with our trial batch of concrete, using a water-cement ratio of 0.81 was only 500 lbs. per sq. in. We then draw a curve parallel with the basic curve which we have established as shown in Fig. 10 and we find that to obtain a modulus of rupture of 550 lbs. per sq. in. we should have used a water-cement ratio just slightly in excess of 0.75. We then should proceed to make up another batch of concrete using the water-cement ratio of 0.75 and a ratio of fine to coarse aggregate determined by trial, so that we finally arrive at a concrete having the desired degree of workability and the desired consistency. This concrete should give the desired strength.

This process of trial mixtures is exceedingly simple and it is recommended that ready-mixed concrete producers become thoroughly acquainted with it. By all means should each plant have established the water-cement ratio compressive-strength and the water-cement ratio-modulus of rupture curves for the particular materials which are being used. With these curves and by the trial batch method of designing concrete, it is a simple matter to proceed as hitherto described to the design of concrete having any required strength. It should not be forgotten, however, that materials change from time to time and that a constant check should be kept on the strength of concrete being produced. A concrete laboratory skilled in this work should be used for this purpose and it would seem that large ready-mixed plants could afford to install their own testing equipment.

In a paper of this nature it is quite impossible to go into the many details of laboratory procedure, nor is it possible to cover fully the many variables which may affect the strength of the concrete. It is hoped, however, that the essential points have been covered and with the procedure described herein it should be possible for the concrete producer to arrive at the desired proportions of concrete in the simplest and most practicable manner.

RUFUS H. DARBY PRINTING CO., INC.
WASHINGTON, D. C.